CASE STUDY INVESTIGATION OF UNSCHEDULED FEEDER AND SCHEDULED TRUNK SERVICE RELATIONSHIPS IN CAPE TOWN

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ABSTRACT

The large-scale replacement of unscheduled minibus-taxi services with scheduled bus rapid transit trunk-feeder networks in South African cities, as envisioned in the 2007 Public Transport Strategy, has proven costly and difficult to achieve. Consequently some agencies are exploring the prospects of hybrid networks comprised of scheduled trunk services and unscheduled feeder/distributor services, as a means of achieving a more feasible public transport reform. The operational compatibility of unscheduled feeder/distributor services and scheduled trunk services, however, has not received much research attention. The aim of this paper is to investigate how compatible unscheduled feeder/distributor services and scheduled trunk services might be in the context of the Mitchells Plain public transport interchange in Cape Town. The licensed routes operating out of the Hazeldene minibus-taxi rank serve a catchment area for the train and line-haul bus services that arrive at, and depart from, the interchange. Three main sources of empirical data are used in this case study investigation: seven months of vehicle departure records (n=4,024) obtained from the Hazeldene taxi rank; a five-day passenger transfer survey (n=6,400); and an 11-day vehicle stopping survey (n=1,375). Analysis of these data reveal that, while mean paratransit service headways fluctuate considerably and consistently across the day and from day to day (indicating that paratransit operators are responsive to fluctuations in demand), the limitations of the data prevent detailed analysis of how this impacts passenger transfer time. There is, however, clear evidence that the daily operating hours of unscheduled and scheduled services do not match. It is therefore concluded that, in this case, there are complementarity problems between unscheduled feeder/distributor and scheduled trunk services, and that mitigating public sector intervention is required.

1. INTRODUCTION

The large-scale replacement of unscheduled minibus-taxi services with full specification bus rapid transit trunk-feeder networks in South African cities, as envisioned in the Public Transport Strategy (DoT 2007), has proven costly and difficult to achieve (HvR 2014, von der Heyden *et al* 2015, Behrens and Salazar Ferro 2016). Consequently, some agencies have begun exploring the prospects of hybrid networks comprised of scheduled trunk services and unscheduled feeder/distributor services, as a means of achieving a more feasible public transport reform (Salazar Ferro *et al* 2013, CoCT 2015, Salazar Ferro *et al* 2015, Stoy 2015, Behrens *et al* 2016). The complementarity of unscheduled paratransit feeder/distributor services and scheduled train and bus trunk services with respect to operational efficiency and passenger quality-of-service, however, has not received much research attention.

The aim of this paper is therefore to investigate how compatible unscheduled paratransit feeder/distributor services and scheduled trunk services might be through exploratory research into an actual case of hybridity in Cape Town, and to discuss lessons for how efficient hybrid networks might be facilitated. The case study focusses on the Mitchells Plain public transport interchange. The licensed routes operating out of the Hazeldene minibus-taxi rank, serving neighbourhoods to the west of the Mitchells Plain rail station, serve a catchment area for the train and line-haul bus services that arrive at, and depart from, the interchange.

The paper is divided into five sections. The next section frames the research problem requiring investigation. Section 3 describes the research methods employed, and discusses the limitations of the data analysed. Section 4 reports on research findings with respect to passenger transfer behaviour, passenger boarding capacity, trunk and distributor service headways, and trunk and distributor service spans. Section 5 concludes with discussion on policy implications and future research needs.

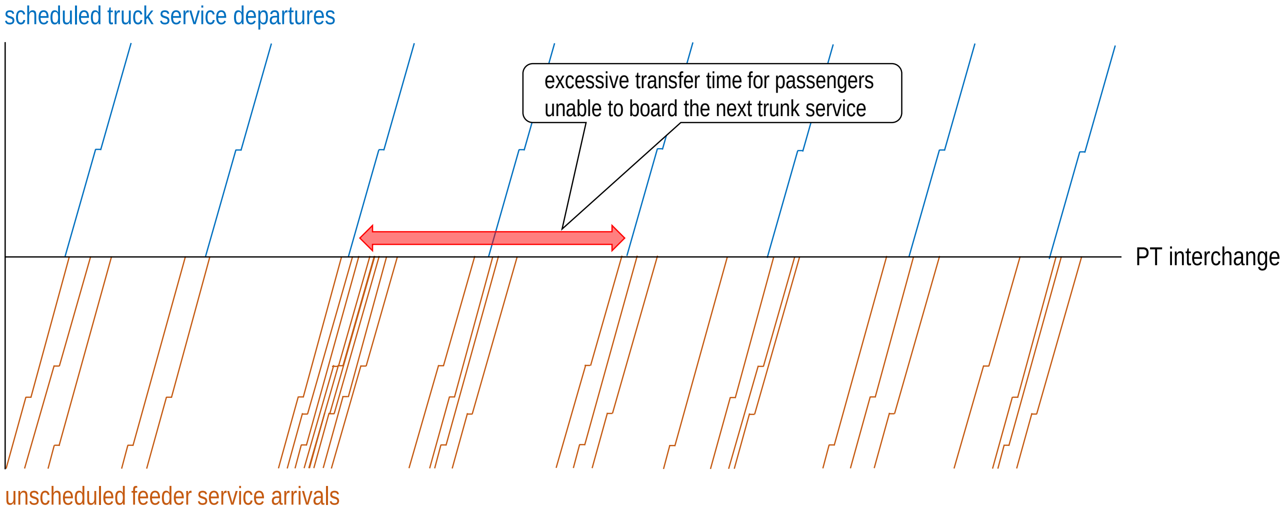
2. RESEARCH PROBLEM

A shift from direct/line-haul service provision to feeder/distributor service provision amongst incumbent unscheduled minibus-taxi operators presents a number of potential problems with respect to operational efficiency and passenger quality-of-service.

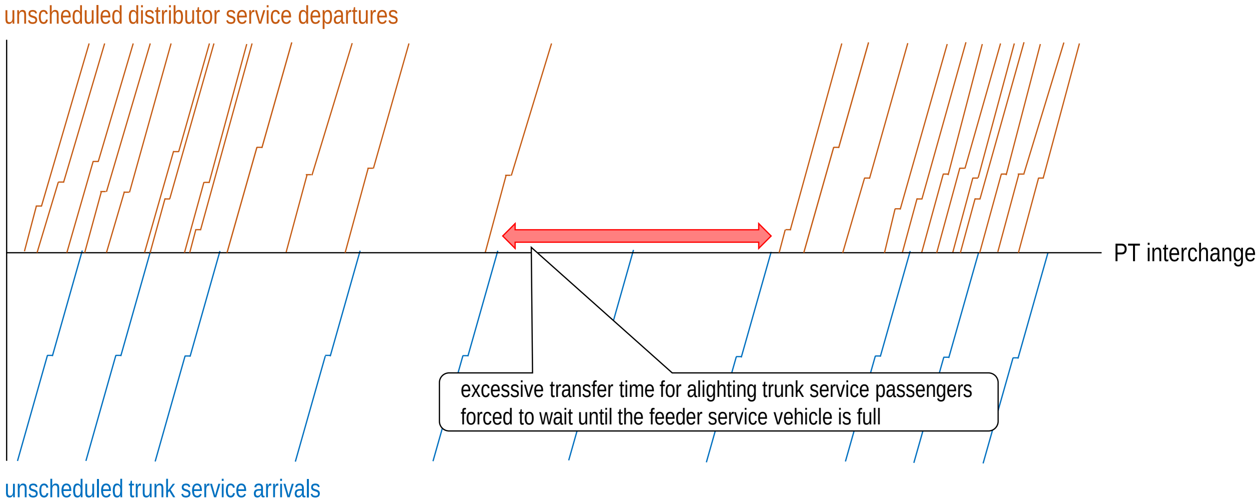
First amongst these is a risk that, in the absence of a centrally planned feeder service schedule, the delivery rate of transferring passengers to public transport interchanges might be heavily uneven and spiked. As illustrated in the time-space chart presented in figure 1(a), this might result in some departing trunk service vehicles having insufficient capacity to carry all the waiting passengers, leading to some passengers enduring excessive transfer times. In instances where scheduled trunk service headways are long (e.g. 20 minutes during off-peak periods), this would present a considerable quality-of-service problem, as studies elsewhere have found that public transport passengers value their waiting time as much as two to three times higher than their in-vehicle travel time (Small 2012).

A second potential problem relates to the departure profile of distributor service vehicles. As illustrated in figure 1(b), if minibus-taxi drivers were to adopt their common 'fill-and-go' behaviour in off-peak periods (i.e. maximising fare box revenue per service kilometre by only departing the rank once the vehicle is full or near-full), then transferring passengers again might be forced to endure excessive transfer times on the return leg of their journey.

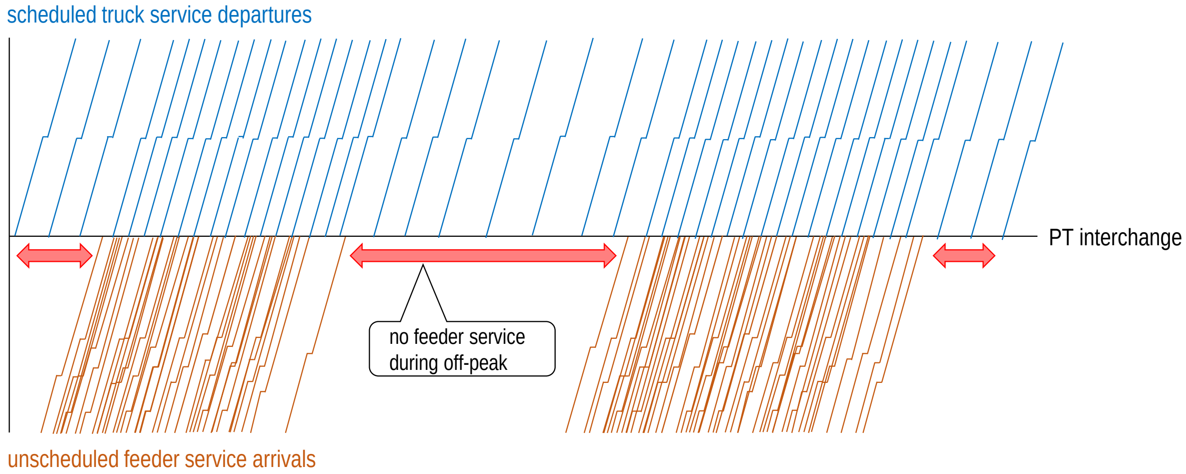
A third potential problem relates to the duration of daily service provision. Unscheduled minibus-taxi operators are under no contractual obligation to provide service at particular times of the day, and may not do so if they perceive the service trip to be uneconomical. As illustrated in figure 1(c), this would result in periods of the day when departing passengers have no feeder service available to begin their trip. Similarly arriving passengers would have no distributor service available to complete their trip.



a. uneven and spiked feeder passenger arrival rates



b. off-peak 'fill-and-go' vehicle departure delays



c. mismatched daily service operating hours

Figure 1. *Potential complementarity problems between scheduled trunk and unscheduled feeder/distributor services*

The current literature on unscheduled-scheduled service hybridity covers: case studies of hybrid public transport networks, including parallel route services (Rivasplata 2000, Lizarraga 2012), shared routes (Hidalgo and Pai 2010), peak-lopping (Behrens *et al* 2016), and feeder-trunk arrangements (Ferreira *et al* 2005, Orrico Filho *et al* 2007, Salazar Ferro *et al* 2015); and the potential impact of a shift from direct/line-haul service to feeder/distributor service provision on the business viability of incumbent paratransit operators (Del Mistro and Behrens 2015). A search of the literature revealed no prior studies exploring the compatibility of scheduled and unscheduled services in trunk-feeder arrangements, and on how any operational efficiency and passenger quality-of-service problems might be overcome. The research reported upon in this paper was initiated to begin to address this gap.

3. RESEARCH METHOD

The research draws from two projects that addressed the research problem in different ways (Hawver 2016 and Birungi 2017). This section describes the case study context, and describes the methods of empirical observation applied in these two projects.

3.1 Case study context

The study area is approximately 19 square kilometres in extent, has a residential population in the region of 160,000, and is located to the west of the Mitchells Plain public transport interchange. The interchange is located some 27 kilometres south-east of the Cape Town city centre. It is comprised of a rail station, bus termini for Golden Arrow and MyCiTi line-haul bus services, and three minibus-taxi ranks to the north, south and west of the rail station. The absence of large-scale employment opportunities in the area necessitates that a large portion of the working population commute considerable distances on a daily basis. The interchange is the third busiest in Cape Town, with approximately 75,000 passengers moving through it each weekday.

Figure 2 illustrates the minibus-taxi service routes that connect the rank on the western side of the public transport interchange (the Hazeldene taxi rank), with two other smaller ranks in the area (at the Liberty Promenade Mall and Westgate Mall). The taxi association operating service routes out of the Hazeldene taxi rank is Hazeldene Shuttle Services. It is a relatively small taxi association, with 31 members and a fleet of 90 vehicles.

The coloured lines on the map illustrate the alignment of the six routes for which minibus-taxi operating licenses have been issued. The dots on the map indicate where passengers were recorded boarding and alighting in the research. In practice, these six licensed routes are consolidated into a single community service route departing from the Hazeldene rank in a clockwise direction, with (as revealed by the vehicle stopping data points) real-time route deviation in response to on-board passenger requests. Some sections of routes 249 and 250 are not served, in order to avoid conflict with an association from the northern rank which holds a partially overlapping route operating license. As noted earlier, the routes operating out of the Hazeldene rank serve a catchment area for the train and line-haul bus services that operate from the public transport interchange.

Source: Birungi (2017)

Figure 2. ***Minibus-taxi vehicle stopping points overlain onto licensed service routes connected to the Hazeldene taxi rank***

For the purposes of charging 'line fees' to members, monitoring that access to the market is equitably distributed, and demonstrating that operating licenses are not dormant, Hazeldene Shuttle Services employs staff (known as 'linesmen') at the Hazeldene rank to manually record the license plate and time of departing vehicles. These secondary longitudinal data offered a unique opportunity to gain insight into the frequency and duration of unscheduled paratransit service operations, and to analyse hybrid trunk-feeder compatibility.

3.2 Vehicle departure observation

The first dataset analysed in the research took the form of the Hazeldene Shuttle Services' daily vehicle departure records. These secondary data took the form of manually completed sheets recording: the date; the vehicle licence plate number; the name of the driver; and the time the vehicle departed the rank. Hazeldene Shuttle Services made seven months of data available, stretching from September 2014 to April 2015 (excluding December 2014). Given the large quantity of paper data (recording in the region of 19,000 vehicle departures), it was necessary to extract a sample. For each month, one week was randomly selected for data capture into an electronic database. A total of 45 days were sampled, representing 22% of the total number of days in the available dataset.

Data capture yielded a sample size of 4,024 vehicle departure records. The data fields included: month; day; date; vehicle license plate number; departure time; and headway (calculated as the elapsed time between successive vehicle departures). Data capture and analysis was undertaken by Hawver (2016), building upon earlier work on a shorter four week period by Jere (2015). Jere (2015) commissioned the 'linesmen' for a week to keep departure records until the last vehicle had departed, in order to ascertain whether the secondary data covered the entire daily service span.

Data analysis took the form of aggregating records into clock hour intervals, and measuring the central tendency and variation of headways for each interval. These measures were then compared with the arrival headways of trunk rail services derived from timetables (see figure 5[b]), and plotted over the course of the day (see figure 5[a]). Therefore, while time-space charts (i.e. figure 5[b] and figure 7[a-f]) create the appearance of uniform departures within each clock hour interval, these are not precise representations of actual headway patterns.

The data have three main limitations. The first is the absence of data from December 2014, and missing data for particular days (24 September, 15 February, 22 March and 3 April), which may have introduced some skew in the analysis. The second limitation is the absence of data on passenger trip origin and destination. Consequently it is unknown what proportion of the departing minibus-taxi passengers had transferred from arriving trunk services. The pattern of distributor service frequency can thus only be partially explained by the demand created by arriving trunk services. Many passengers may use the minibus-taxi services to access retail facilities around the Mitchells Plain public transport interchange, rather than to satisfy feeder or distributor needs. A third limitation, not directly linked to the dataset, is the absence of actual train arrival data. Thus the comparison of distributor service headway patterns with trunk service headway patterns may be inaccurate in instances where train services were either cancelled or running off the scheduled timetable. For the weeks in the dataset, 73% of trains on the Central Line arrived on-time, and 2% of train services were cancelled.

3.3 Passenger travel survey

The second dataset analysed in the research was derived from a five-day passenger intercept survey, and an associated 11-day on-board vehicle stopping survey, conducted for the purposes of building a micro-simulation model of minibus-taxi services in the catchment area (Birungi 2017).

A pilot test of the passenger intercept survey involved asking eastbound pedestrians exiting the Hazeldene taxi rank (with the railway serving as a screenline) to indicate their destination, choosing from: train; MyCiTi bus; Golden Arrow bus; the two minibus-taxi ranks on the eastern side of the railway; or land use activities surrounding the Mitchells Plain public transport interchange. These data were captured for one day (Friday, 20 November 2015), between 06h00 and 18h00. A total of 6,632 pedestrians were surveyed in this way, over a time period of 11 hours. The subsequent main passenger intercept survey was conducted on five weekdays in November 2015, between 06h00 and 18h00. The survey instrument recorded the mode onto which arriving feeder service passengers transferred. Arriving passengers who terminated their trip were not recorded. A total of 6,400 transferring passengers were surveyed in this way, over a total time period of 60 weekday hours.

From the perspective of the questions raised in this research, the passenger intercept data have two main limitations. The first is that pedestrians intercepted at the Hazeldene taxi rank during the pilot survey included those walking in from adjacent neighbourhoods, and those terminating their trip at the Mitchells Plain town centre. Consequently the data does not enable pedestrians who were transferring passengers to be distinguished from pedestrians who were not public transport passengers, minibus-taxi passengers who did not transfer to another mode, or passengers walking to board trunk rail and buses services as their first public transport mode. The second limitation is the restriction of transfer data to just arriving feeder service passengers in the main intercept survey. Consequently the possible effects of driver ‘fill-and-go’ behaviour on transfer times cannot be explored, as this would require data on departing distributor service passengers as well. The exclusion of non-transferring passengers also precluded any analysis of the relative proportion of arriving minibus-taxi passengers who transferred to other modes at the interchange, and those who ended their trip.

The on-board vehicle stopping survey involved fieldworkers repeatedly travelling the length of the service route, and recording information whenever the vehicle stopped. The survey was conducted on 11 days (Tuesday to Saturday) in November 2015, between 06h00 and 17h30. At each vehicle stopping event, the fieldworker (seated behind the side door) recorded the number of passengers boarding and alighting the vehicle. Where applicable, the fieldworker also recorded the amount of hailing passengers unable to board because the vehicle was full. Other information collected included: the vehicle's licence plate number; the date and time of the stopping event; and the location coordinates of the stop. The time and location of the stop were recorded using the Geographical Positioning System (GPS) capability of mobile telephones, and an open-source tool (Open Data Kit). A total of 1,375 vehicle stopping events were recorded in the database (see figure 2 for a plot of these data points in space).

The main limitation of the vehicle stopping data is that, while the boarding and alighting data enables analysis of the extent to which waiting passengers are left behind due to lack of space in the departing vehicle, there are no data on how long these passengers had to wait at the rank (or at the roadside) until the next vehicle departed, and therefore how badly this impacted quality-of-service.

4. RESEARCH FINDINGS

These datasets were analysed in order to develop insight into: the extent to which minibus-taxi passengers transfer from, or to, train or line-haul bus services; the capacity of minibus-taxi vehicles to board all waiting passengers; the extent to which fluctuations in the headway of departing minibus-taxis match fluctuations in the headway of arriving scheduled train and bus services across peak and off-peak periods; and the extent to which the daily duration of unscheduled distributor services matches the daily duration of scheduled trunk services.

4.1 Passenger transfers

The passenger transfer survey data collected by Birungi (2017) at least confirms that the service routes connecting to the Hazeldene taxi rank serve as feeder, and by inference distributor, services for trunk or line-haul modes operating from the Mitchells Plain public transport interchange. A considerable number of minibus-taxi passengers arriving at the Hazeldene taxi rank were found to transfer directly onto other modes. On average, 1,280 weekday passengers transferred to other modes, with the greatest number transferring to rail services (58%), followed by line-haul minibus-taxis operating from the two ranks on the eastern side of the rail station (30%), Golden Arrow buses (8%), and MyCiTi buses (4%) (see figure 3[a]).

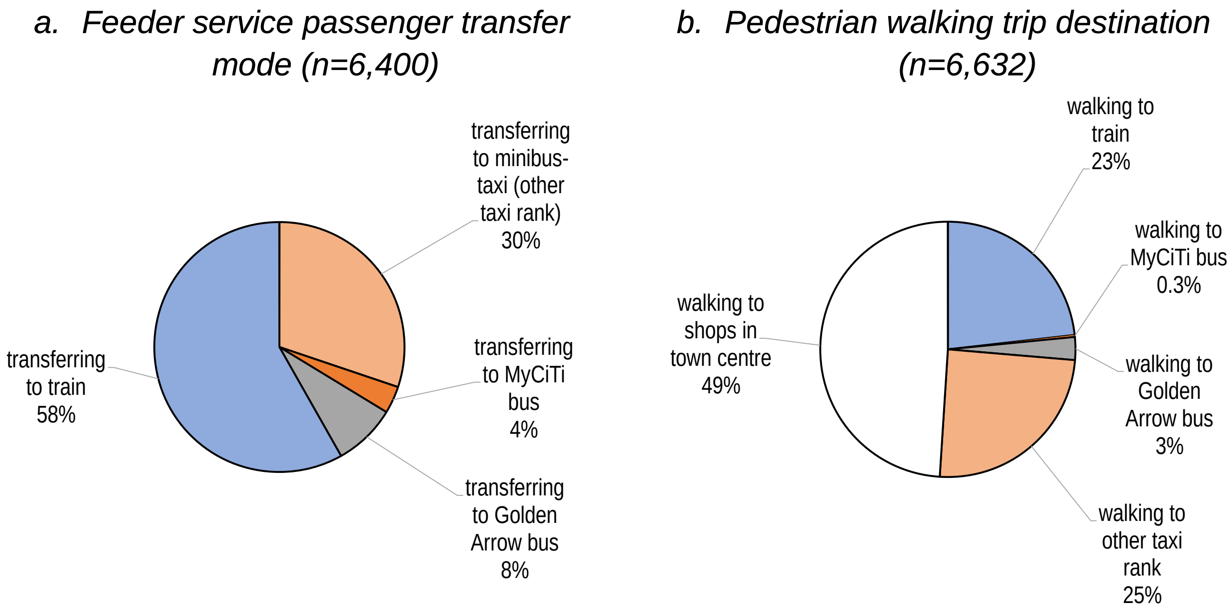
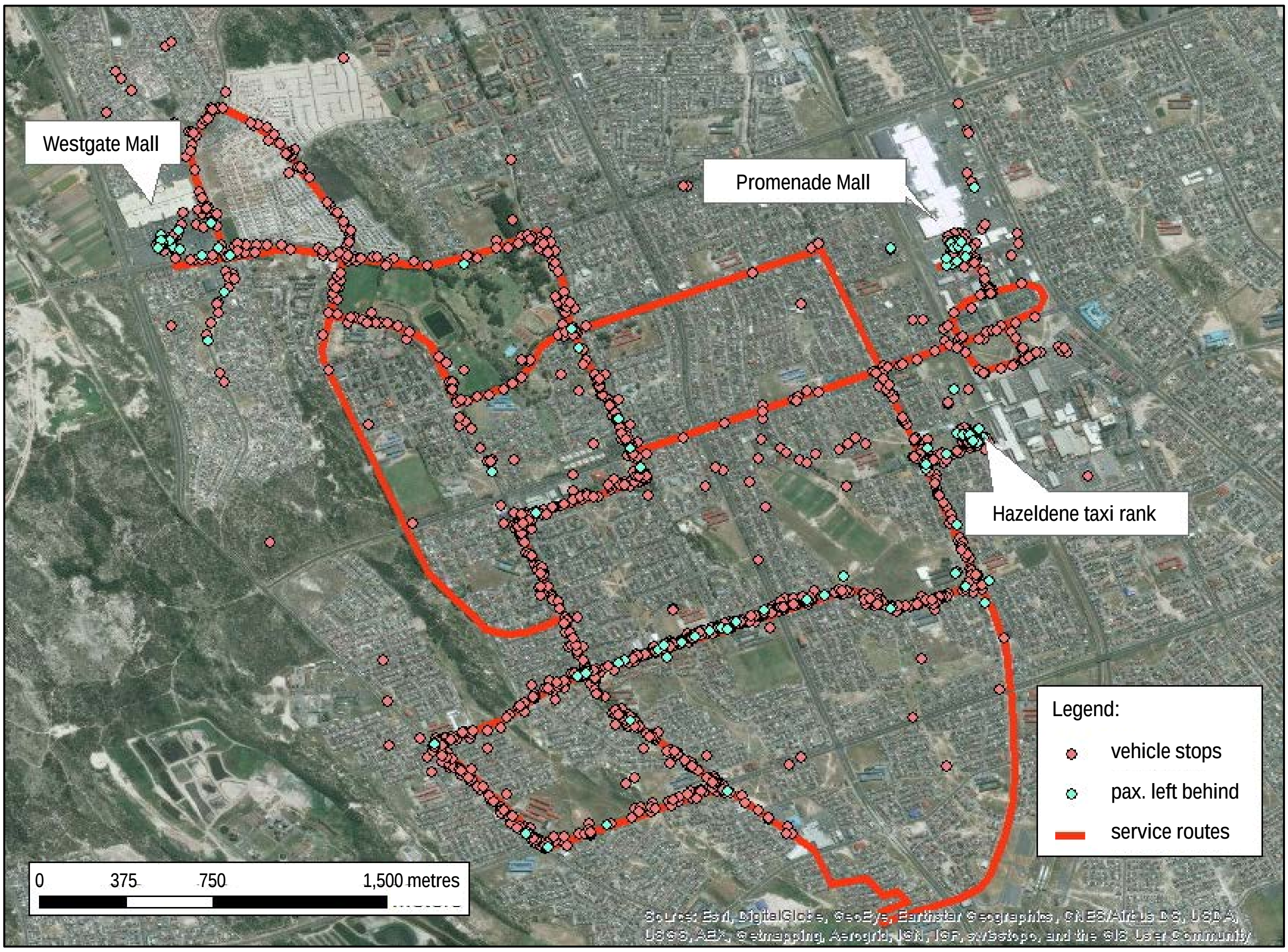


Figure 3. ***Destinations of intercepted transferring passengers and pedestrians at the Hazeldene minibus-taxi rank***

Assuming that the one day of data captured in the pilot intercept survey is broadly representative of all weekdays, the data presented in figure 3(b) suggests that a considerable number of passengers arriving at the Hazeldene taxi rank from surrounding residential neighbourhoods also use the minibus-taxi services as a means of accessing the commercial activities at the Mitchells Plain town centre, and do not engage in intermodal transfers. It was found that of the 6,632 pedestrians walking through the Hazeldene taxi rank, 49% were accessing activities adjacent to the Mitchells Plain town centre. The remaining 51% indicated they were walking to other public transport modes, but it cannot be determined precisely how many of these 3,384 passengers were transferring from minibus-taxis or walking to their first mode of public transport. The results of the main passenger transfer survey, however, suggest that in the region of 38% (1,280) of these minibus-taxi passengers might have been transferring to line-haul or trunk services, and 62% (2,104) were simply walking through the taxi rank to access their first mode of public transport.

The GPS-based vehicle stopping survey data analysed by Lyles (2016) recorded 4,610 passengers boarding and 3,671 passengers alighting during the data collection period (indicating that some alighting passengers were missed in data collection). Of the 1,375 stopping events, on 96 (7%) occasions the vehicle was unable to board all waiting passengers. Figure 4 illustrates that most incidences of a departing vehicle having insufficient capacity to board all waiting passengers occurred at the three taxi ranks, and along the busiest sections of the service route. Of the passengers observed waiting at the rank for a vehicle, or hailing a vehicle on the road, 5% were unable to board (Lyles 2016).



Source: Lyles (2016)

Figure 4. ***Passengers unable to board at minibus-taxi vehicle stopping events (n=1,375)***

These boarding and alighting findings imply that 'fill-and-go' behaviour amongst drivers, and associated excessive transfer times, may not be as pervasive at the Hazeldene taxi rank as might be expected. The boarding of passengers along the service route, and often soon after departing the rank, suggests that vehicles are not always departing full. Conversely, the waiting passengers left behind at the rank indicates that there are times when inadequate distributor service capacity is provided. The impact of this on quality-of-service, however, cannot be established in the absence of data on how long these passengers had to wait for the next vehicle to board. The analysis of distributor service headways presented in the next section (see figures 5[a] and 6) suggests that if this failure to accommodate all waiting passengers occurred at the times when maximum headways were recorded (typically ranging between 10 and 45 minutes), this would present a considerable quality-of-service problem.

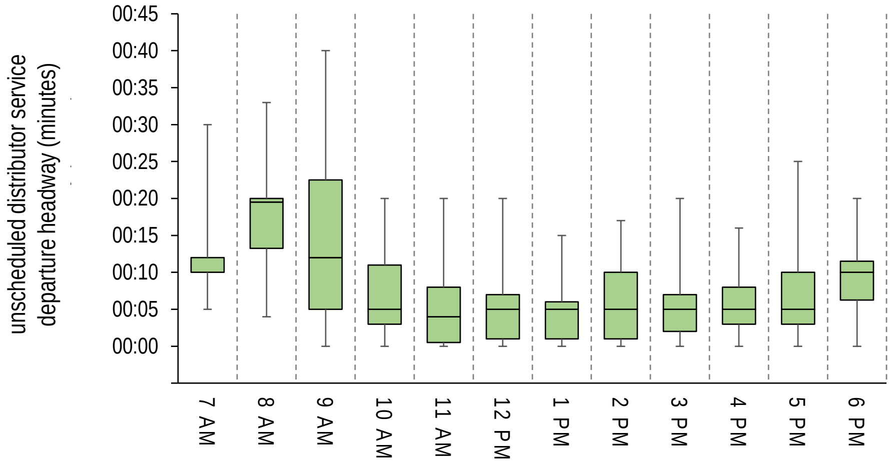
4.2 Service headways and spans

Analysis of the vehicle departure observation data revealed that unscheduled minibus-taxi distributor service departure headways fluctuate across the day, and that these fluctuations are fairly consistent over time. Figure 5(a) presents the quartile distribution of departure headways for a typical weekday (Wednesdays). The box plots show that median headways are highest in the morning peak period, decreasing in the late morning and afternoon. This pattern is broadly intuitive, as the tidal pattern of passenger flows in Cape Town would result in demand for distributor services increasing in the afternoon when commuters return from work (the demand for feeder services would be the inverse). Headway variance also decreases in the late morning and afternoon. Figure 6 indicates that headway distributions on other weekdays are similar to Wednesdays, but that Saturdays and Sundays are unique. The smallest median headways (~3 minutes) were observed during the midday shopping peak on Saturdays.

Figure 5(b) presents a comparison of mean unscheduled distributor service departure headways with scheduled train arrival headways for a typical weekday (Wednesdays). Figure 7 indicates that trunk-distributor headway patterns on other weekdays are similar to those observed on Wednesdays, but that Sundays are significantly different. The comparison reflects increases in distributor service headways that are consistent with lower volumes of train passengers arriving in the morning peak period. The short headways at midday, however, cannot be explained by trunk service arrivals. The headway pattern suggests that a significant number of other trip purposes are being served, which is consistent with the insight gained into the extent of intermodal transfer discussed in the previous section. Minibus-taxi operators thus appear responsive to daily fluctuations in passenger demand, but these fluctuations are not well explained by trunk service passenger arrivals. This was confirmed by the chair of Hazeldene Shuttle Services in a post-analysis interview, who also noted that minibus-taxi associations operating from the northern rank on the eastern side of the railway had begun serving their catchment area as well, with the result that Hazeldene Shuttle Services' departure headways were not an accurate representation of the total distributor service supply (Trevor Martin pers comm 2016).

The comparison of service headways presented in figures 5(b) and 7, however, does enable much clearer findings with respect to service span. The daily operating hours of unscheduled distributor and scheduled trunk services evidently do not match. Train arrivals continue well after the cessation of minibus-taxi service supply. This mismatch is particularly acute on Sundays. It was found, somewhat unexpectedly, that a scheduled minibus-taxi feeder service is provided between 04h30 and 06h30 to ensure that early train commuters can access the rail station (but no equivalent distributor services are provided during this period). Operators are incentivized to provide this early morning service through the offer of preferential access to passengers at the rank when the peak starts. Comparisons with Golden Arrow and MyCiTi bus service timetables, by Jere (2015), yielded patterns of service span mismatch similar to train services.

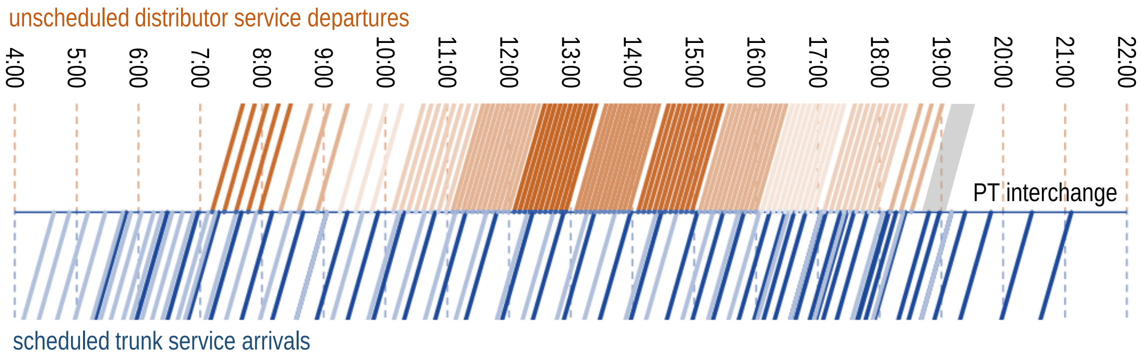
When questioned on the reasons for this difference in service spans, the chair of Hazeldene Shuttle Services explained that minibus-taxis stopped operating at 19h10 because of both a decline in passenger demand (which reduces service viability), and security concerns (on-board cash holding makes minibus-taxi vehicles crews particularly vulnerable at the end of the day). He noted that, in the past, distributor services were offered by the association until 21h00, but these were withdrawn to reduce exposure to crime.



Notes:

1. Boxes indicate the inter-quartile range for each clock hour interval. Whiskers indicate minimum and maximum headway values.

a. quartile distribution of distributor service departure headways



Notes:

1. Orange colour tones indicate different clock hour intervals.
2. The grey block between 18h30 and 19h10 – revealed in Jere's (2015) primary data collection, and confirmed in an interview with the chair of Hazeldene Shuttle Services (Trevor Martin pers comm 2017) – represents a period of distributor service provision not captured in the association's vehicle departure records.
3. Light blue indicates northbound arrivals; dark blue indicates southbound arrivals.
4. Time space curves are purely illustrative, and do not indicate the actual speed of arriving trains and departing minibuses.

b. trunk service arrival and distributor service departure headways

Figure 5 ***Trunk service arrival and distributor service departure headways (Wednesday) (n=627)***

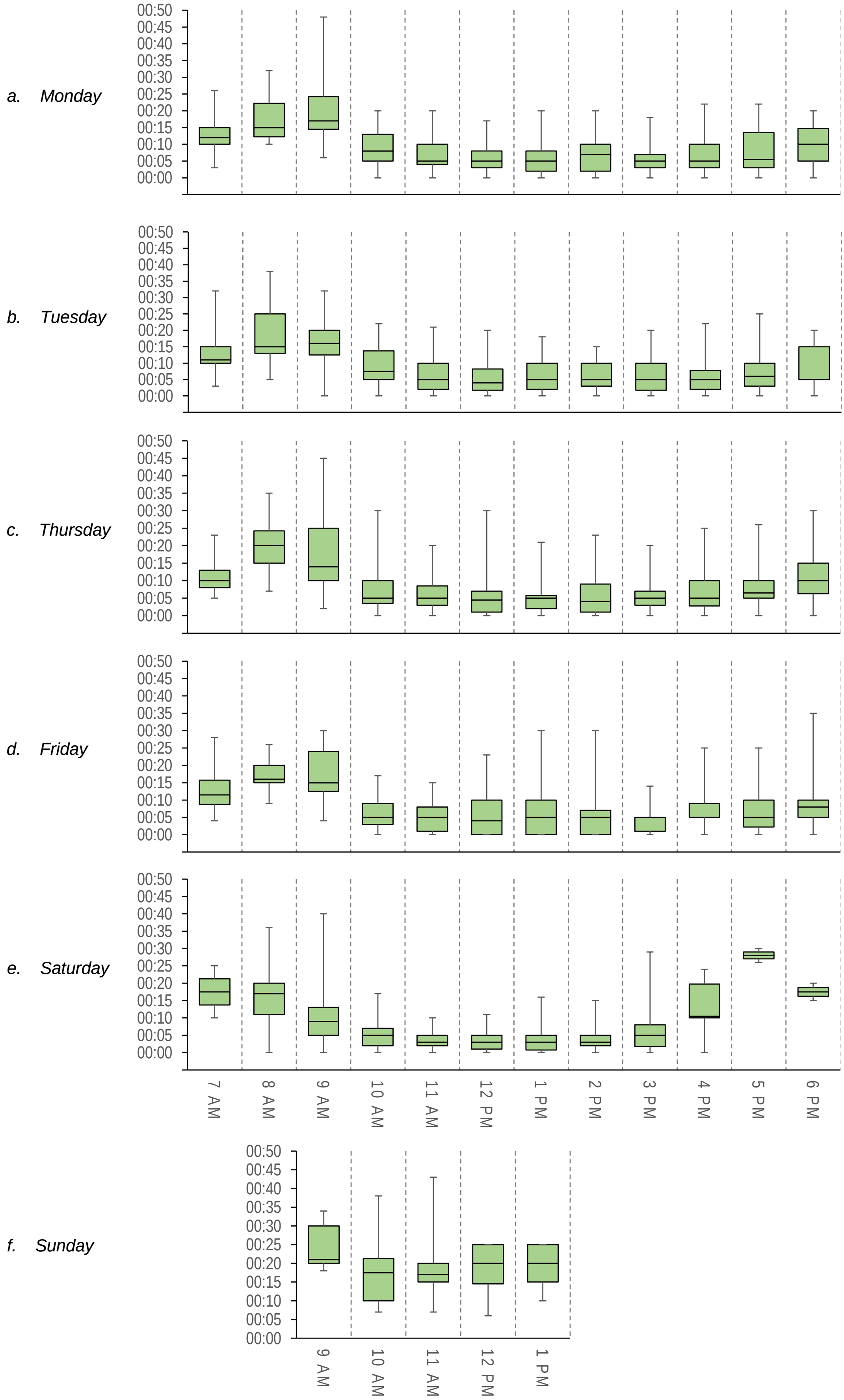


Figure 6. ***Quartile distribution of distributor service departure headways, by day (n=3,397)***

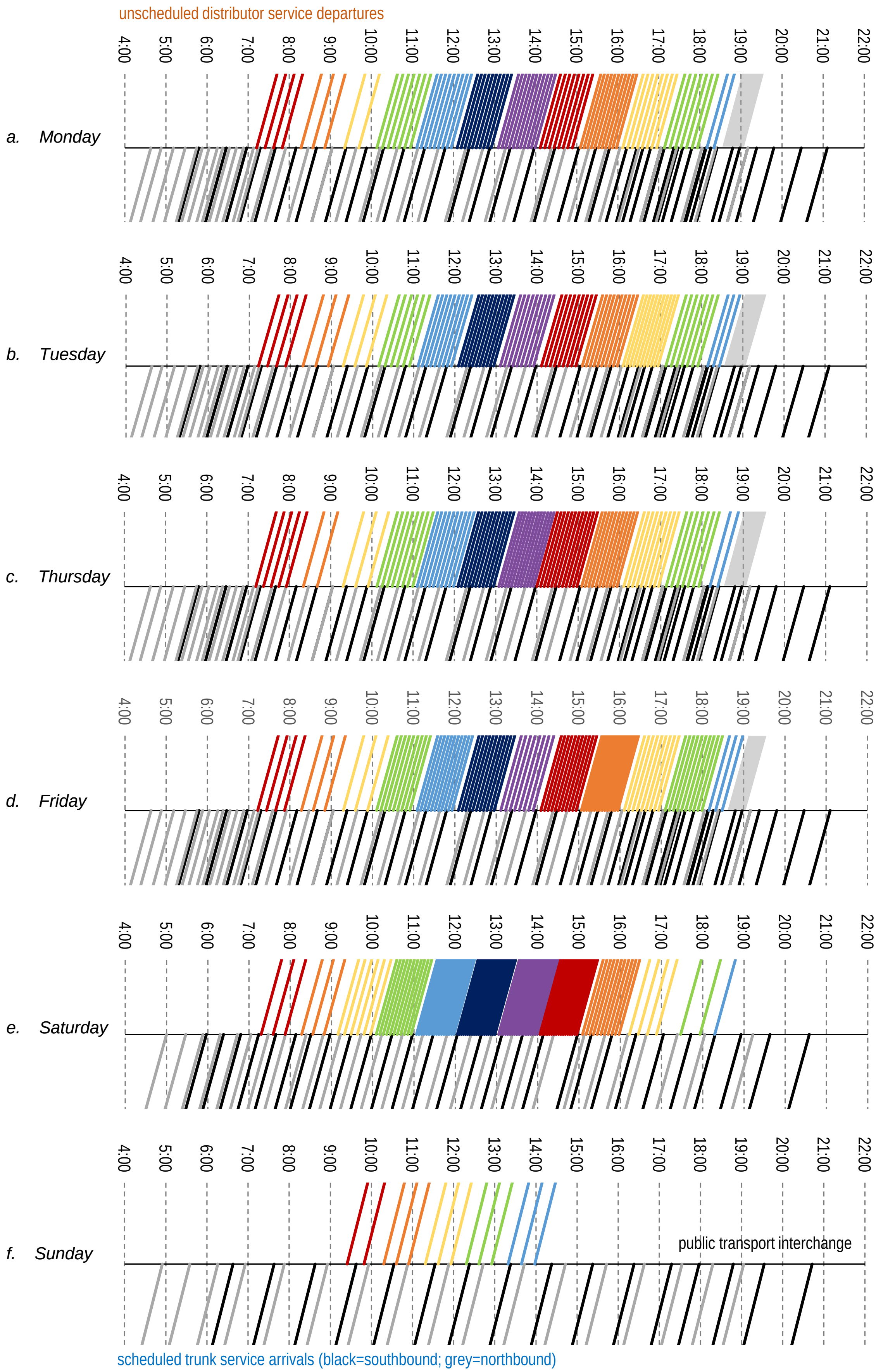


Figure 7. ***Trunk service arrival and distributor service departure headways, by day (n=3,397)***

5. CONCLUSION

This paper set out to explore how compatible unscheduled feeder/distributor services might be with scheduled trunk services, and to discuss lessons the Mitchells Plain case study might have for how successful hybridity can be achieved.

There is clear evidence in the case study of unscheduled service headway fluctuations that are consistent across a significant period of time. This suggests that minibus-taxi operators are responsive to fluctuations in passenger demand in a systematized way. However, it is also clear that many passengers use the services provided as a means of accessing the Mitchells Plain town centre, and do not transfer to other public transport modes, so the extent of demand responsiveness specifically to the feeder/distributor needs of trunk service passengers cannot be determined. Further, the boarding of passengers on-route suggests that ‘fill-and-go’ behaviour is not a universal practice, but evidence of failure to board all waiting passengers at ranks, while a small percentage, indicates that there are times when feeder/distributor service supply is insufficient. The limitations of the data prevent detailed analysis of how this impacts passenger transfer time and quality of service. What can be concluded categorically, however, is that there is a mismatch between daily scheduled trunk and unscheduled feeder/distributor service operating hours. It is therefore concluded that, in this case, there are complementarity problems between unscheduled feeder/distributor and scheduled trunk services, and that the private sector on its own is unlikely to produce a fully coordinated hybrid service network.

The key policy implication of this conclusion is that public intervention will be required to incentivize service provision throughout the daily duration of trunk service supply, and to address the security concerns of operators. Cashless fare collection holds particular promise in this regard as a means of both enabling incentivizing fare bonus payments at selected times of the day, and of removing the need for large amounts of cash to be carried on-board (a theme explored by Schalekamp *et al* 2017).

The research presented in this paper was exploratory in nature, and many more research questions require attention. Arising directly from the limitations of the available case study data, further research is needed to measure the waiting time of transferring passengers more accurately, and to gauge satisfaction with the attributes of the feeder/distributor services on offer. A benchmarking of these measurements against scheduled feeder/distributor services in other locations would be instructive. Analysis of other case studies is also needed to enable some estimation of the degree to which the feeder-trunk arrangements at the Hazeldene taxi rank are representative of other interchanges in the public transport network. Finally, public interventions to incentivize more complementary feeder-trunk hybridity need to be developed, tested, monitored and evaluated.

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